Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Cross Section Evaluation Working Group (CSEWG) Overview

David Brown

National Nuclear Data Center

28 February 2022

@BrookhavenLab

Before ENDF

By 1960, there were many data efforts worldwide

- different formats
- often hard-coded libraries
- proprietary data
- Notable efforts: UKNDL (AWE, UK), NDA library (US), ENDL (LRL, US)

~1962 H. Honeck (BNL), A. Henry (Westinghouse), G. Joanou (GA) met at Colony Restaurant in DC decided on action

- requested Reactor Mathematics and Computation Division of ANS to sponsor 2 meetings to link databases

http://www.streetsofwashington.com/2013/10/fine-dining-in-washington-dc-in-1950s.html

Brookhaven National Laboratory

The Cross Section Evaluation Working Group produces ENDF/B library

Formed 1966 & Chaired by BNL

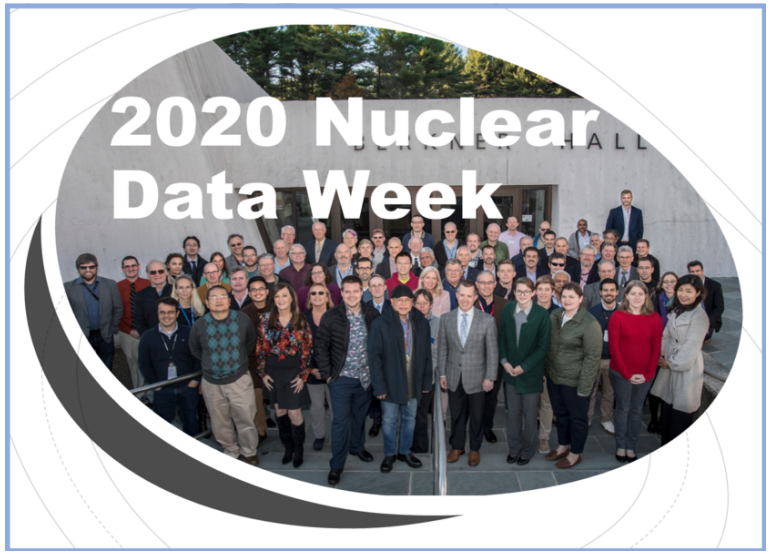
Collaboration of many US programs, industry and international partners

- If you see something in the library, at some point a sponsor somewhere wanted it

All steps of nuclear data pipeline coordinated through CSEWG

Depending on what needs done, getting required data in library can be major effort

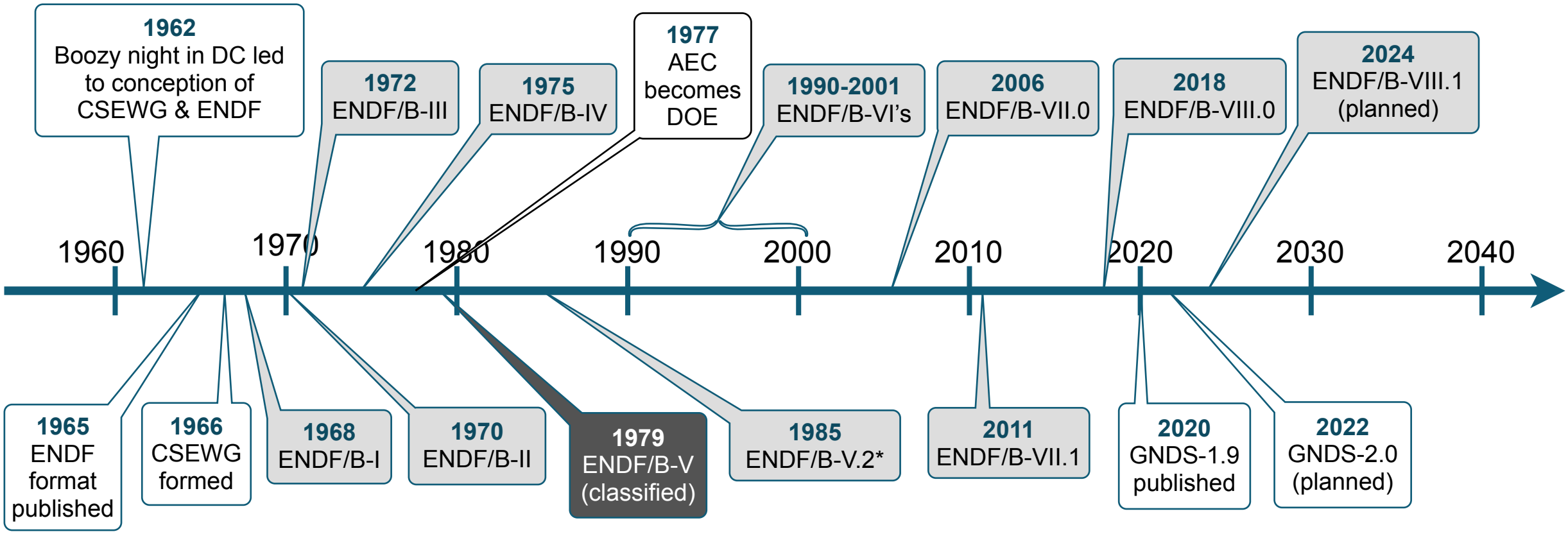
We are always open to new users and collaborators



The December 2020 Nuclear Data Week at BNL was virtual. The picture was from the 2019 meeting and reminds us of better days.

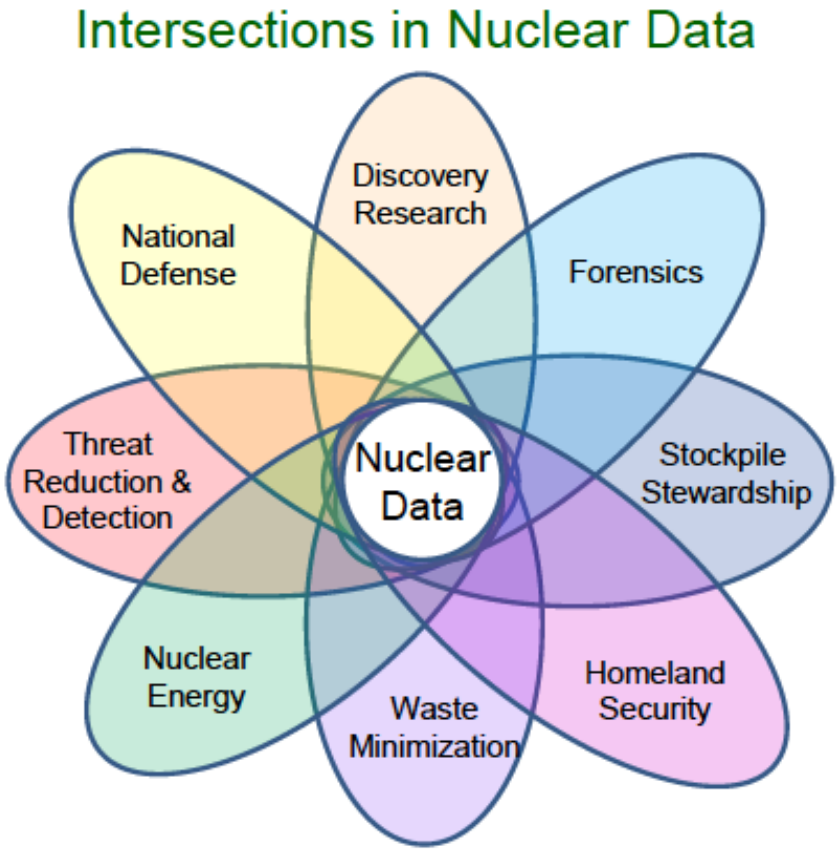
Brookhaven National Laboratory

ENDF Timeline

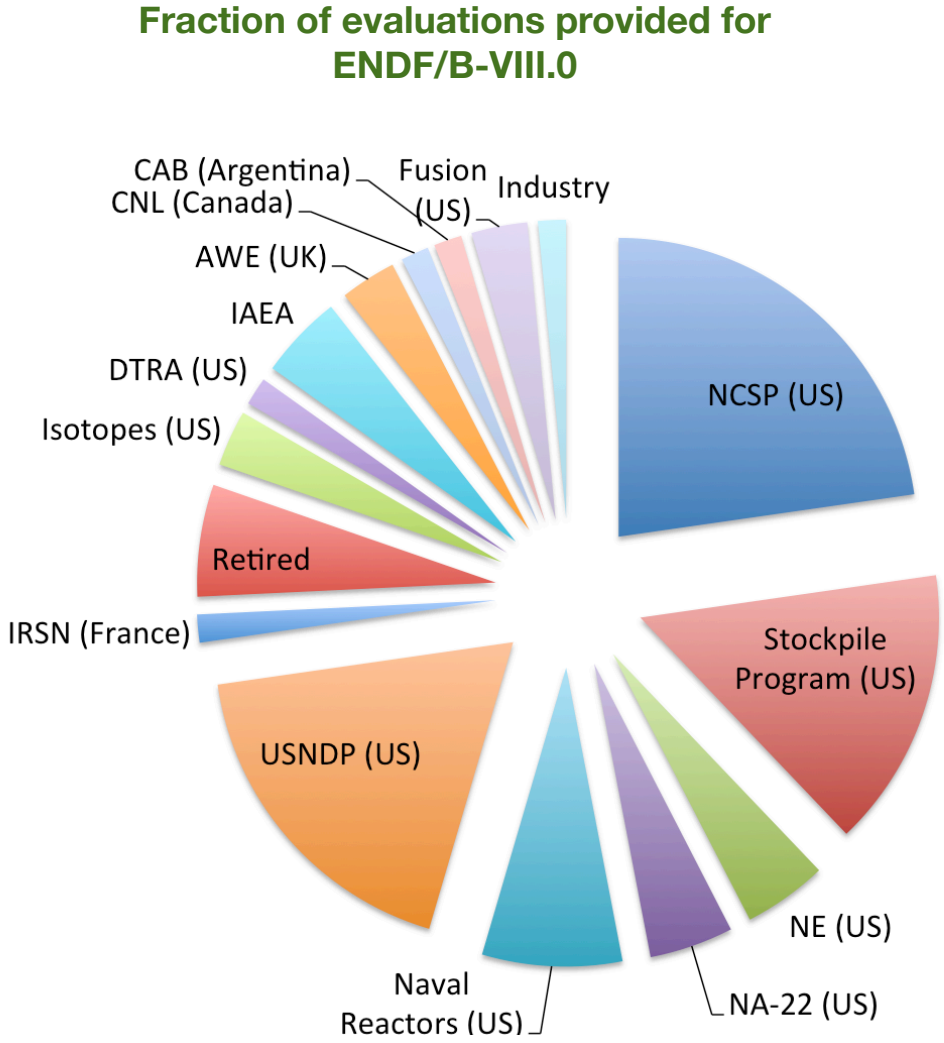


* everybody's favorite release

CSEWG is a long standing collaboration between the data users who are also the biggest content providers



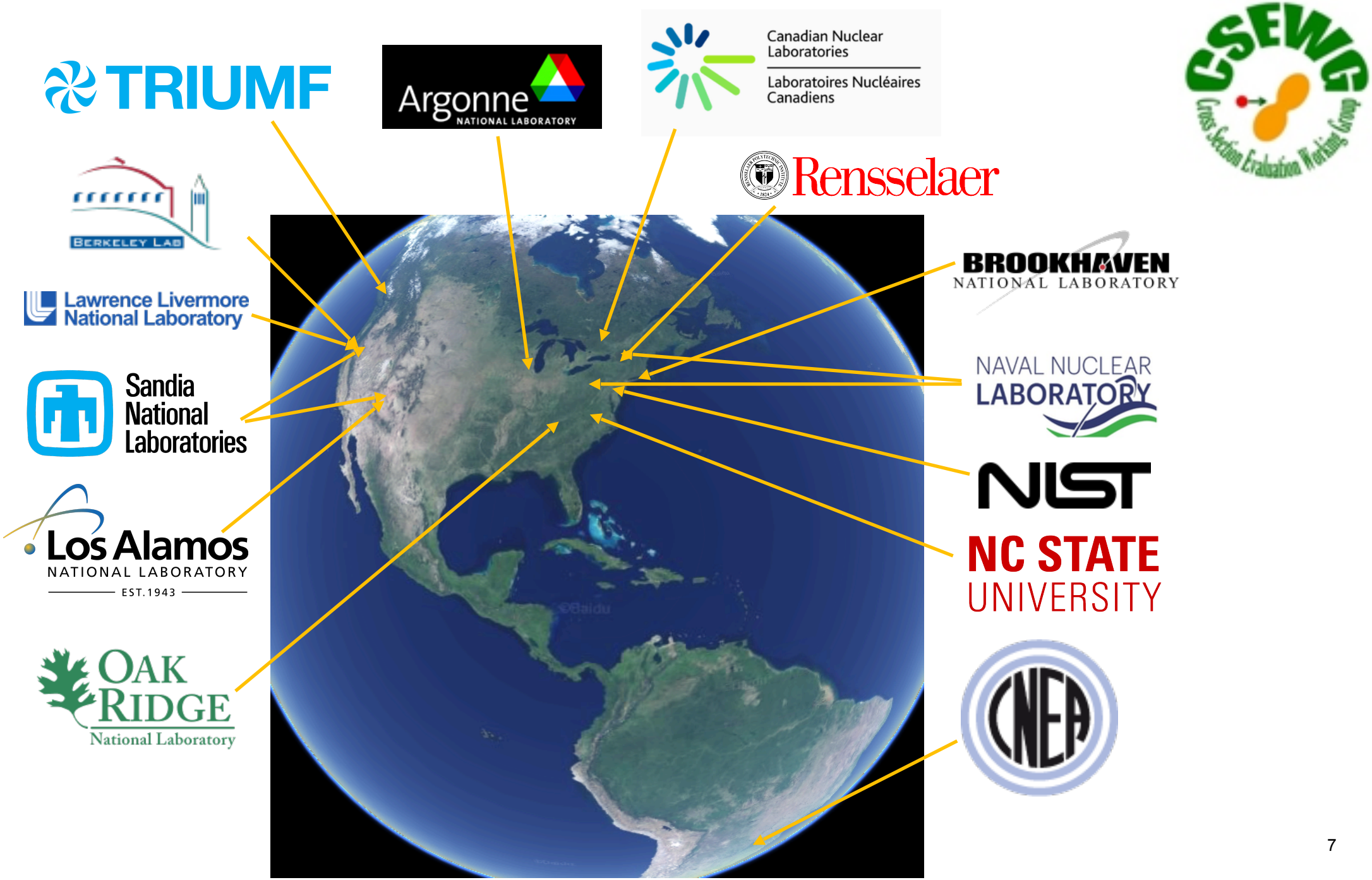
Dr. Timothy Hallman, Associate Director of the Office of Science for Nuclear Physics
April 5, 2015



Brookhaven National Laboratory

By sharing through CSEWG many sponsors reap the benefit of collaboration

Program	Measure-ment	Theory	Comp-ilation	Eval-uation	QA (V&V, IE)	Infra-structure (gitlab, etc.)
DTRA	✓					
International (IAEA,NEA,…)	✓	✓	✓	✓	✓	✓
NA-22	✓	✓		✓		
Naval Reactors	✓			✓	✓	
NCSP	✓	✓		✓	✓	✓
Nucl. En.					✓	
Other (NP, ICF, …)	✓	✓				
Defense Prog.	✓	✓		✓	✓	✓
USNDP	✓	✓	✓	✓	✓	✓

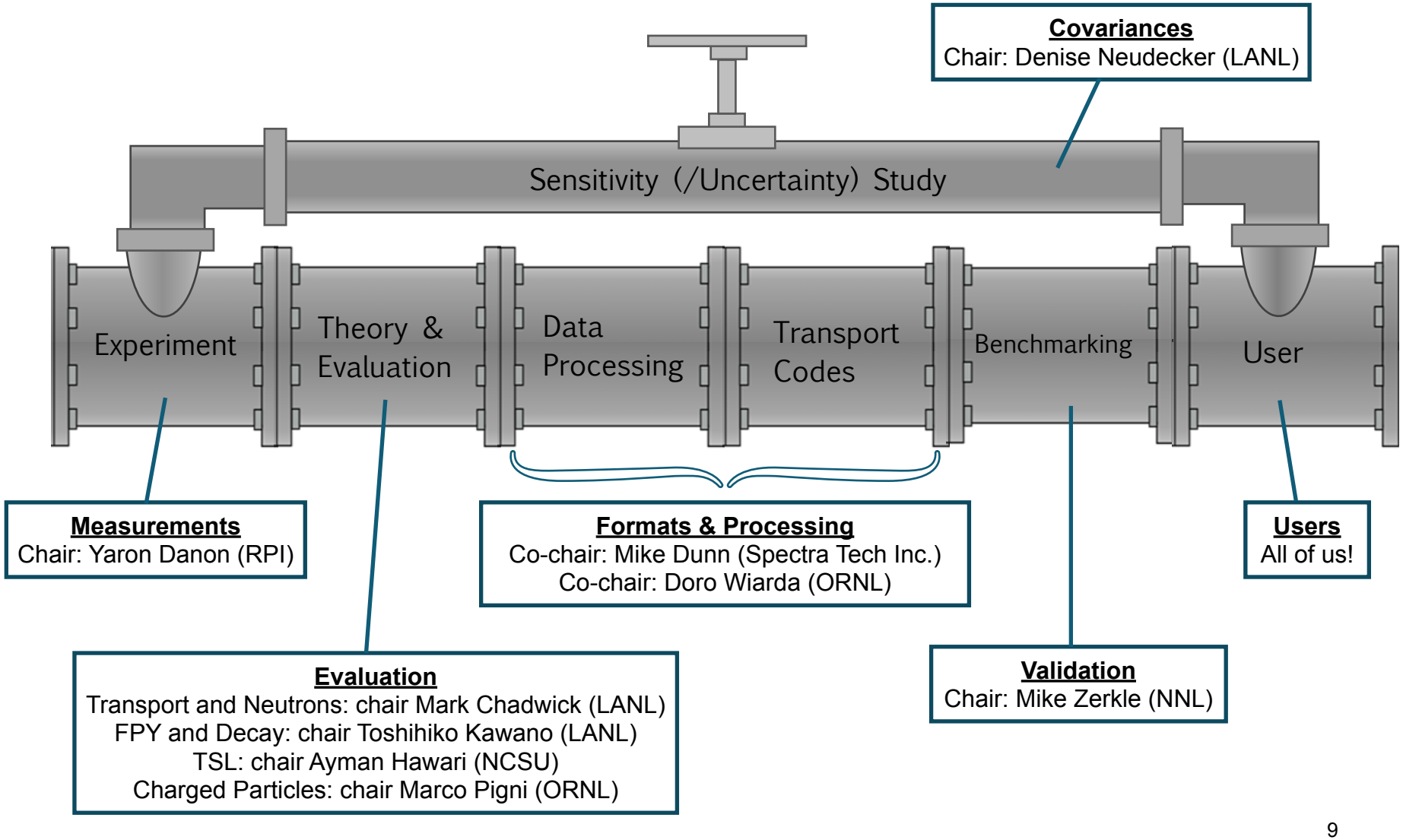

TRIUMF
Argonne NATIONAL LABORATORY
Canadian Nuclear Laboratories
Laboratoires Nucléaires Canadiens
CSEWG
Cross Section Evaluation Working Group
Rensselaer
BERKELEY LAB
Lawrence Livermore National Laboratory
BROOKHAVEN NATIONAL LABORATORY
Sandia National Laboratories
NAVAL NUCLEAR LABORATORY
NIST
Los Alamos NATIONAL LABORATORY EST. 1943
NC STATE UNIVERSITY
OAK RIDGE National Laboratory
CNEA

CSEWG is not limited to the Americas

All steps of nuclear data pipeline are coordinated through CSEWG

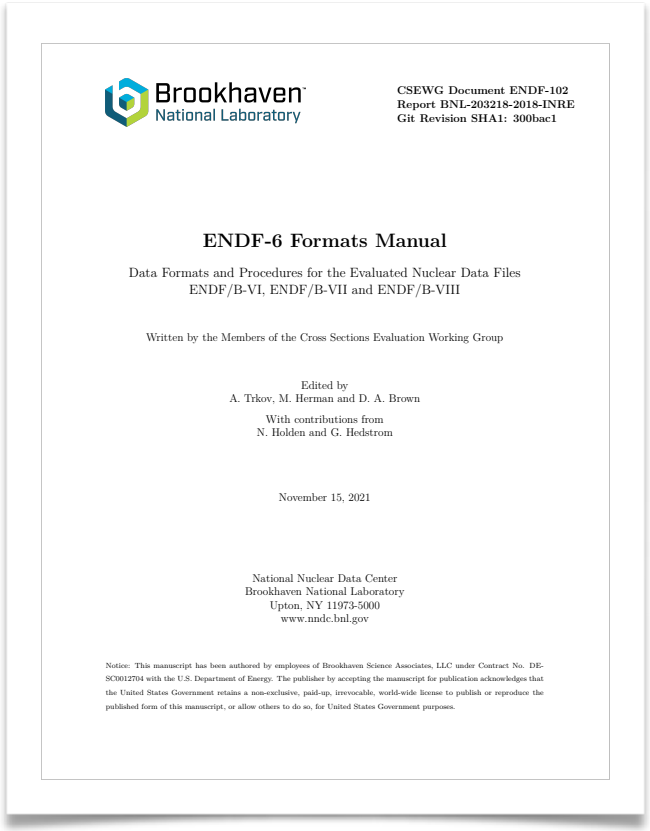
Chair:
David Brown (BNL)
dbrown@bnl.gov

Library Manager:
Gustavo Nobre (BNL)
gnobre@bnl.gov



Brookhaven National Laboratory

ENDF Formats



Brookhaven National Laboratory

CSEWG Document ENDF-102
Report BNL-203218-2018-INRE
Git Revision SHA1: 300bac1

ENDF-6 Formats Manual

Data Formats and Procedures for the Evaluated Nuclear Data Files
ENDF/B-VI, ENDF/B-VII and ENDF/B-VIII

Written by the Members of the Cross Sections Evaluation Working Group

Edited by
A. Trkov, M. Herman and D. A. Brown

With contributions from
N. Holden and G. Hedstrom

November 15, 2021

National Nuclear Data Center
Brookhaven National Laboratory
Upton, NY 11973-5000
www.nndc.bnl.gov

Notice: This manuscript has been authored by employees of Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the U.S. Department of Energy. The publisher by accepting the manuscript for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this manuscript, or allow others to do so, for United States Government purposes.

ENDF Releases

ELSEVIER

Volume 148, February 2018 ISSN 0090-3752

Nuclear Data Sheets

A Journal Devoted to Compilations and Evaluations of Experimental and Theoretical Results in Nuclear Physics

E. A. McCutchan, Editor
National Nuclear Data Center, Brookhaven National Laboratory, Upton, NY 11973-5000, USA
www.nndc.bnl.gov

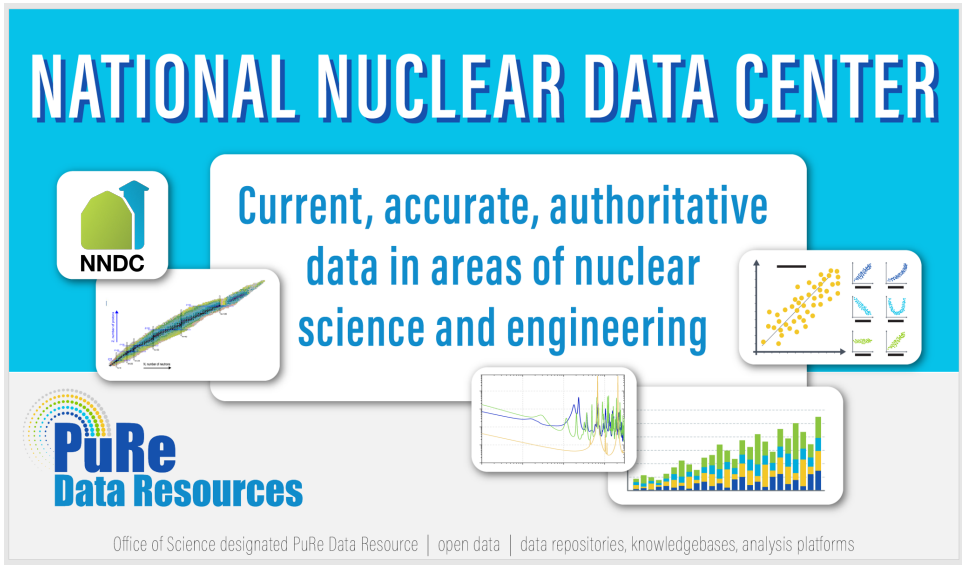
Special Issue on Nuclear Reaction Data

Special Issue Editor: Pavel Obložinský
Special Issue Assistant Editor: Boris Pritychenko

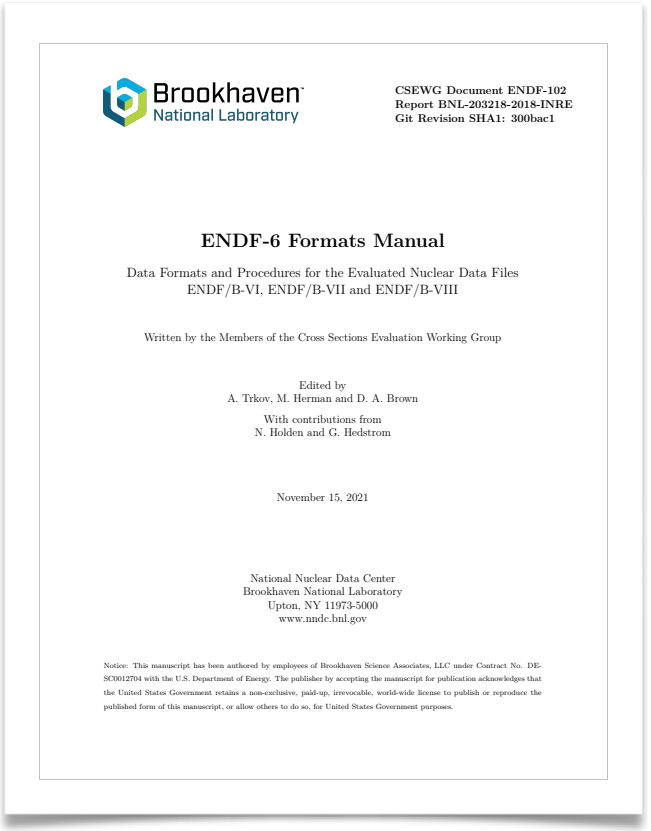
Contents

Contents continued on the back cover page

ENDF Files



ENDF Formats



Brookhaven National Laboratory

CSEWG Document ENDF-102
Report BNL-203218-2018-INRE
Git Revision SHA1: 300bac1

ENDF-6 Formats Manual

Data Formats and Procedures for the Evaluated Nuclear Data Files
ENDF/B-VI, ENDF/B-VII and ENDF/B-VIII

Written by the Members of the Cross Sections Evaluation Working Group

Edited by
A. Trkov, M. Herman and D. A. Brown

With contributions from
N. Holden and G. Hedstrom

November 15, 2021

National Nuclear Data Center
Brookhaven National Laboratory
Upton, NY 11973-5000
www.nndc.bnl.gov

Notice: This manuscript has been authored by employees of Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the U.S. Department of Energy. The publisher by accepting the manuscript for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this manuscript, or allow others to do so, for United States Government purposes.

ENDF Releases

ELSEVIER

Volume 148, February 2018 ISSN 0090-3752

Nuclear Data Sheets

A Journal Devoted to Compilations and Evaluations of Experimental and Theoretical Results in Nuclear Physics

E. A. McCutchan, Editor
National Nuclear Data Center, Brookhaven National Laboratory, Upton, NY 11973-5000, USA
www.nndc.bnl.gov

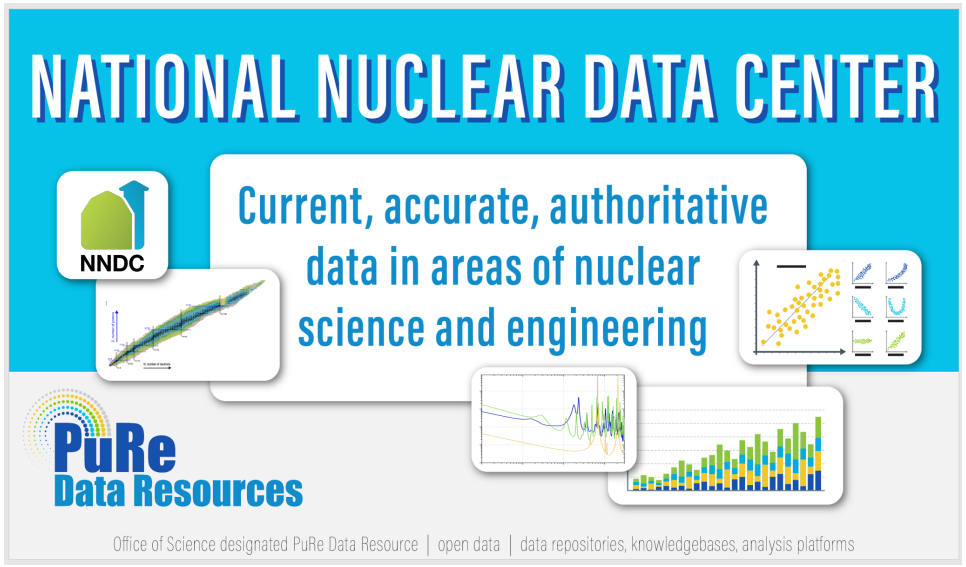
Special Issue on Nuclear Reaction Data

Special Issue Editor: Pavel Obložinský
Special Issue Assistant Editor: Boris Pritychenko

Contents

Contents continued on the back cover page

ENDF Files



ENDF format & ontology was (and still is) tied to original infrastructure

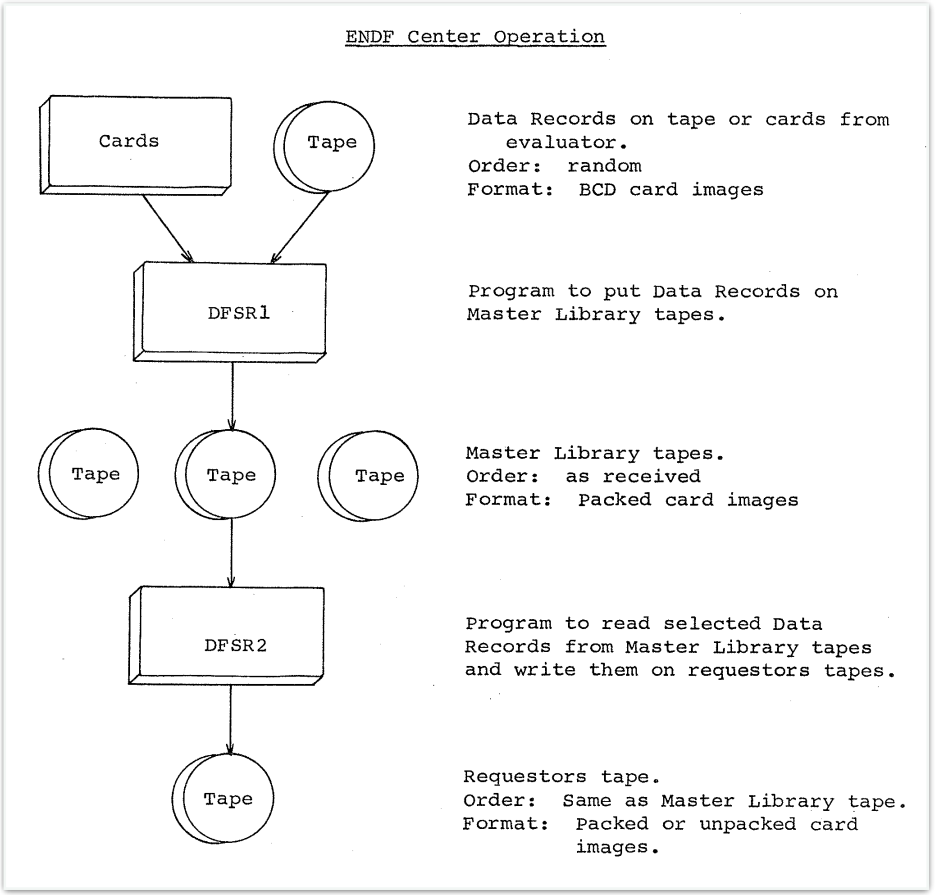
Original format designed to fit on IBM 80 column punchcards

- Evaluations actually were occasionally submitted on punchcards

Original data stored on magnetic tapes

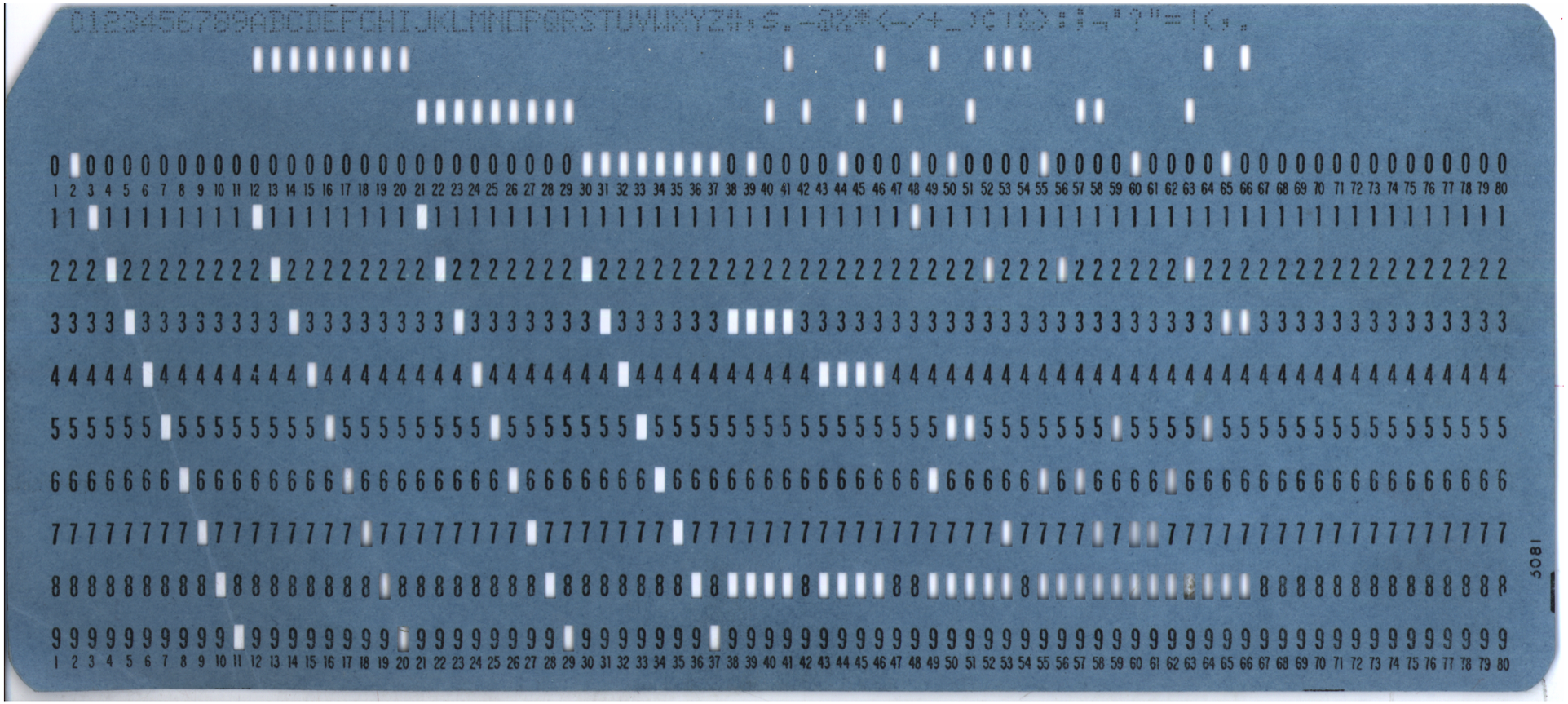
It was possible to request ENDF data on tapes and/or punchcards

- Punchcard format was discouraged, BNL was trying to phase them out



From BNL-8381 (1966)

This is an IBM 80 column punchcard



https://en.wikipedia.org/wiki/Punched_card#/media/File:Blue-punch-card-front-horiz.png

Brookhaven National Laboratory

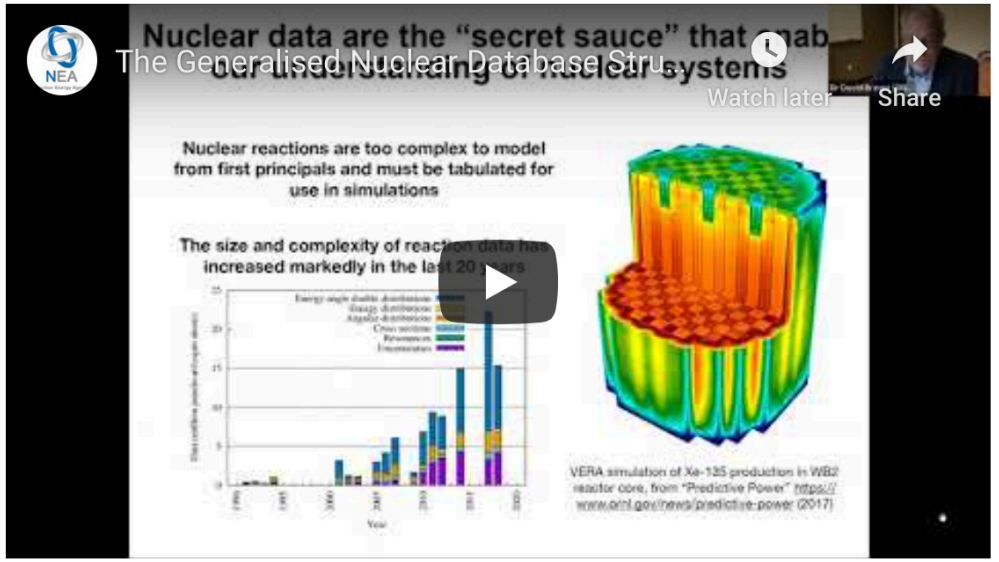
This is a chunk of the n+59Co evaluation: it's punchcard-ready

```
                                  14          83           1          02725 1451   286
                                  14          84           1          02725 1451   287
                                  14          85           1          02725 1451   288
                                  14          86           1          02725 1451   289
                                  14          87           1          02725 1451   290
                                  14          88           1          02725 1451   291
                                                                        2725 1  099999
                                                                        2725 0  0      0
 2.705900+4 5.842690+1           0           0           1          02725 2151     1
 2.705900+4 1.000000+0           0           0           1          02725 2151
 1.000000-5 1.000000+5           1           3           0          12725 2151     3
 3.500000+0 6.672000-1           0           0           2          32725 2151     4
 5.842690+1 6.672000-1           0           0         600        1002725
-5.000000+3 3.000000+0 5.576800+2 9.215100+0 0.000000+0 0.000000+02725
-5.000000+3 4.000000+0 1.898100+2 1.868200-1 0.000000+0 0.000000+02725
-4.767000+2 4.000000+0 1.949000-2 2.148900+0 0.000000+0 0.000000+02725
-2.258800+2 3.000000+0 9.164400+0 5.214100-2 0.000000+0 0.000000+02725
 1.320000+2 4.000000+0 5.270100+0 4.700000-1 0.000000+0 0.000000+02725
 4.323100+3 4.000000+0 1.041400+2 4.173700-1 0.000000+0 0.000000+02725
 5.016000+3 3.000000+0 6.789601+2 1.332200+0 0.000000+0 0.000000+02725
 6.389700+3 4.000000+0 1.681100+0 3.155600-1 0.000000+0 0.000000+02725
```

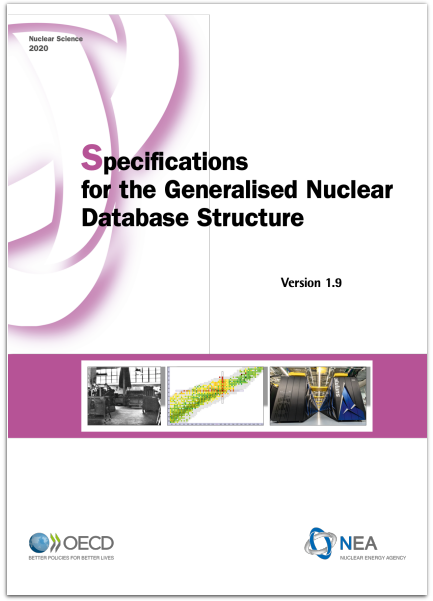
Line number, so you can put your punchcards back in order if you drop them

Brookhaven National Laboratory

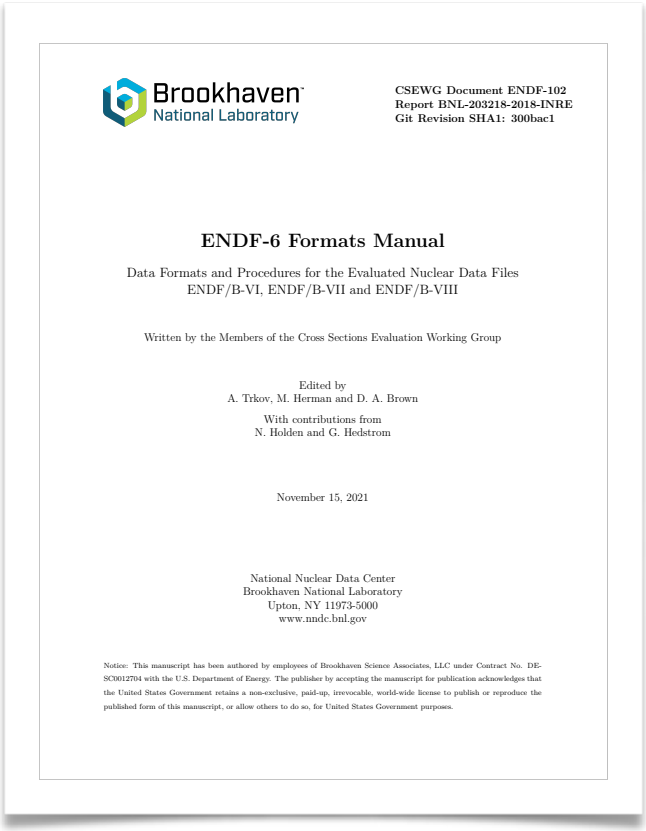
ENDF & GNDS Formats



- **New NCSP relevant formats**
  - Mixed elastic scattering TSL data for nuclides with both coherent and incoherent components (M. Zerkle NNL)
  - Background R-matrix format (J. Brown ORNL)
- **GNDS & ENDF have similar format approval process**
  - Harness power of gitlab
  - Contact D. Brown (EG-GNDS chair) or D. Wiarda (ENDF Formats chair) for information
- **GNDS-1.9 published**
  - Specifications: https://oecd-nea.org/download/wpec/documents/7519-GNDS.pdf
  - XML Schema for GNDS-1.9: https://www.oecd-nea.org/download/wpec/gnds/gnds.xsd
  - GNDS Webinar: https://www.youtube.com/watch?v=h9Byrkxr8LE&feature=youtu.be
- **GNDS-2.0 approved by Expert Group, will submit to full WPEC in May**



ENDF Formats



Brookhaven National Laboratory

CSEWG Document ENDF-102
Report BNL-203218-2018-INRE
Git Revision SHA1: 300bac1

ENDF-6 Formats Manual

Data Formats and Procedures for the Evaluated Nuclear Data Files
ENDF/B-VI, ENDF/B-VII and ENDF/B-VIII

Written by the Members of the Cross Sections Evaluation Working Group

Edited by
A. Trkov, M. Herman and D. A. Brown

With contributions from
N. Holden and G. Hedstrom

November 15, 2021

National Nuclear Data Center
Brookhaven National Laboratory
Upton, NY 11973-5000
www.nndc.bnl.gov

Notice: This manuscript has been authored by employees of Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the U.S. Department of Energy. The publisher by accepting the manuscript for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this manuscript, or allow others to do so, for United States Government purposes.

ENDF Releases

ELSEVIER

Volume 148, February 2018 ISSN 0090-3752

Nuclear Data Sheets

A Journal Devoted to Compilations and Evaluations of Experimental and Theoretical Results in Nuclear Physics

E. A. McCutchan, Editor
National Nuclear Data Center, Brookhaven National Laboratory, Upton, NY 11973-5000, USA
www.nndc.bnl.gov

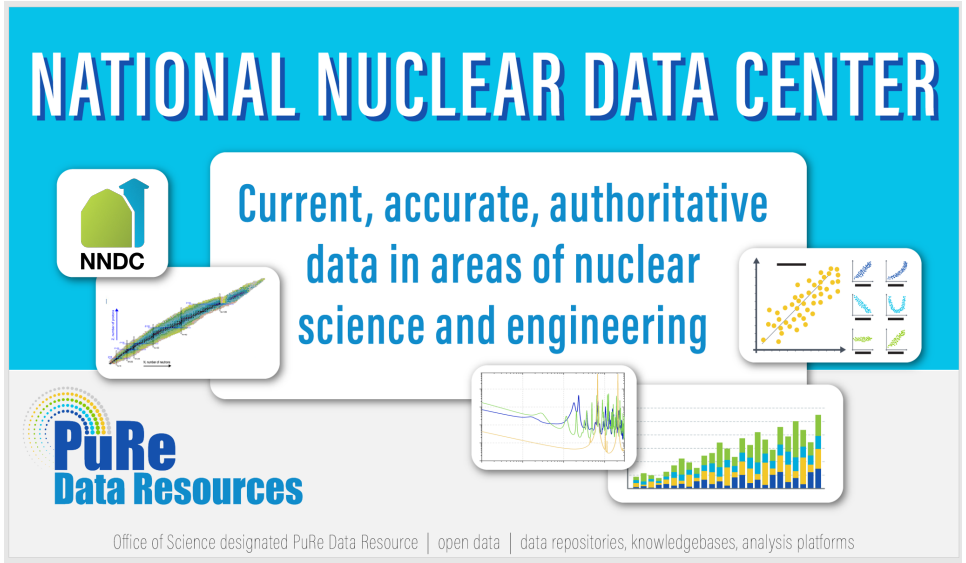
Special Issue on Nuclear Reaction Data

Special Issue Editor: Pavel Obložinský
Special Issue Assistant Editor: Boris Pritychenko

Contents

Contents continued on the back cover page

ENDF Files



ENDF/B-VIII.0 was released on 2 Feb. 2018 by the Cross Section Evaluation Working Group (CSEWG)

Integrates contributions for many sources

- **Neutron Standards** *IAEA, NIST*
- **CIELO Pilot Project** *BNL led Fe, LANL led ^{16}O and ^{239}Pu, IAEA led $^{235,238}U$*
- **Many new and improved neutron evaluations** *(DP, Crit. Safety, NE, USNDP)*
- **New thermal scattering libraries** *(Crit. Safety, Naval Reactors)*
- **Charged particles** *USNDP (LLNL)*
- **New atomic data** *(LLNL)*
- **Success rests on EXFOR library** *IAEA project but USNDP (BNL) coordinates compilation of reaction data for Western Hemisphere*

* ENDF/B-I was released in June 1968

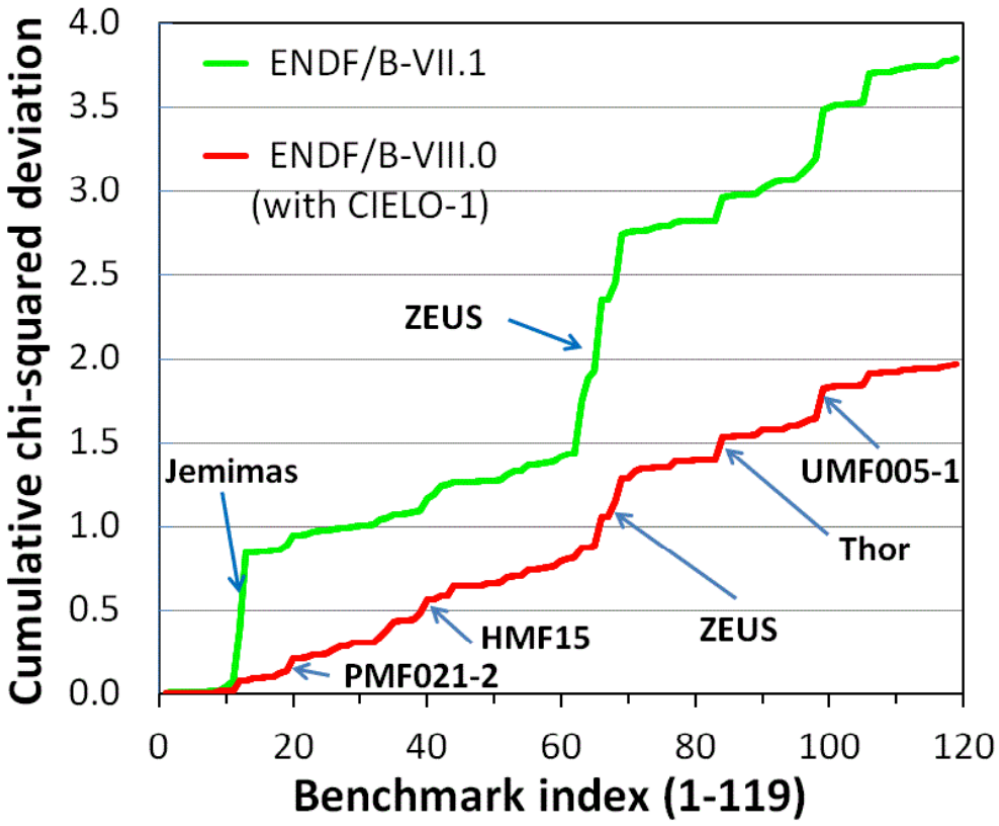
ENDF/B-VIII.0 is our best performing and highest quality library yet

Validate by simulating well characterized systems

- 1198 critical assembly benchmarks
- 14 MeV source transmission
- Many other tests

Quality also assured by

- ADVANCE continuous integration system at BNL
- Annual Hackathons



M.B. Chadwick et al, Nuclear Data Sheets 148, 189 (2018)

Brookhaven National Laboratory

Library and evaluations detailed in Nuclear Data Sheets vol. 148 (2018)

ENDF/B-VIII.0: D. Brown *et al.*,
Nuclear Data Sheets 418, 1 (2018)

Neutron Data Standards: A. Carlson *et al.*,
Nuclear Data Sheets 418, 143 (2018)

CIELO Overview: M.B. Chadwick, *et al.*,
Nuclear Data Sheets 148, 189 (2018)

CIELO Iron: M. Herman, *et al.*,
Nuclear Data Sheets 148, 214 (2018)

CIELO Uranium: R. Capote, *et al.*,
Nuclear Data Sheets 148, 254 (2018)

PFNS evaluation: D. Neudecker, *et al.*,
Nuclear Data Sheets 148, 293 (2018)

^{239}Pu(n,g) measurement: S. Mosby, *et al.,*
Nuclear Data Sheets 148, 312 (2018)

^{235}U PFNS measurement: M. Devlin, *et al.*,
Nuclear Data Sheets 148, 322 (2018)

Next ENDF/B Release

ENDF/B VIII.1

Last ENDF/B release (VIII.0): Feb. 2018

"Minor" release (VIII.1) targeted for Feb. 2023

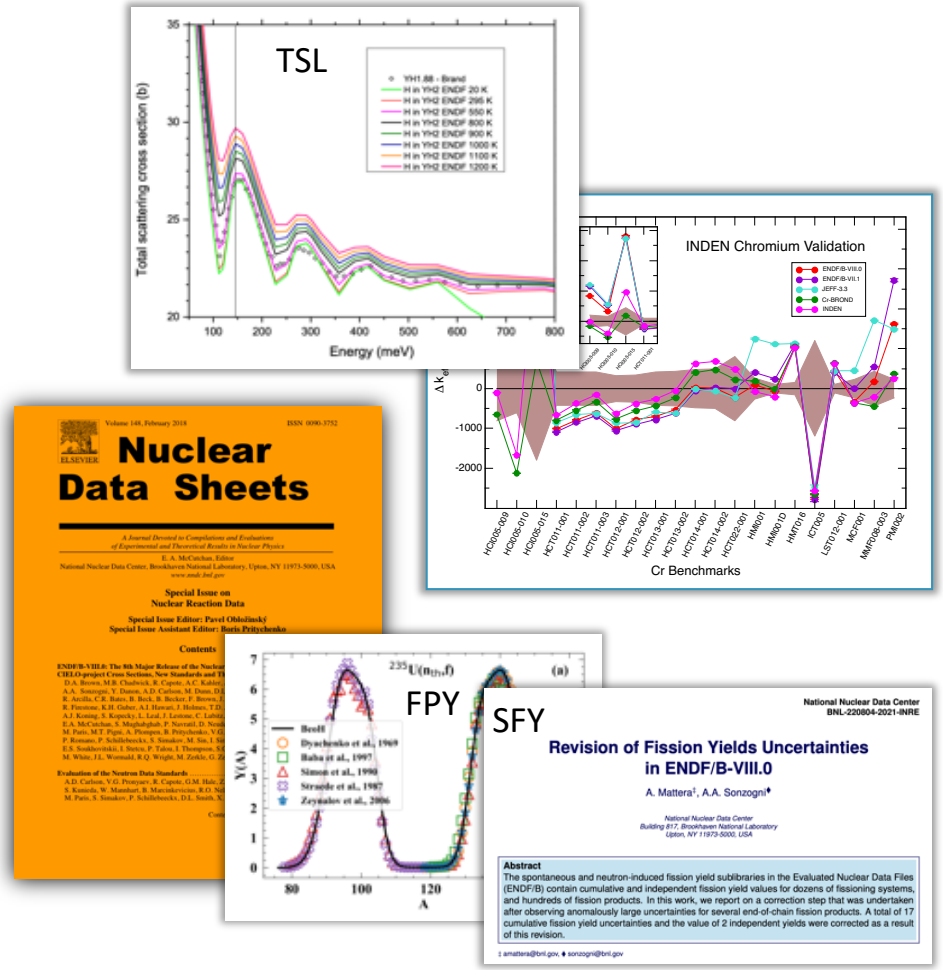
- Only ENDF major releases contain new Standards evaluations.
- INDEN (^{56}Fe, ^{50,52,53,54}Cr, $^{28\text{-}30}$Si, ^{16,18}O, ^{233,235}U, ^{239}Pu, …)
- TSL (FLiBe, paraffinic oil, HF, ZrH_x, …)
- FPY
- More is coming!

New evaluations directly impact new reactor concepts (e.g. SMR, MSR, …)

New BNL Leadership

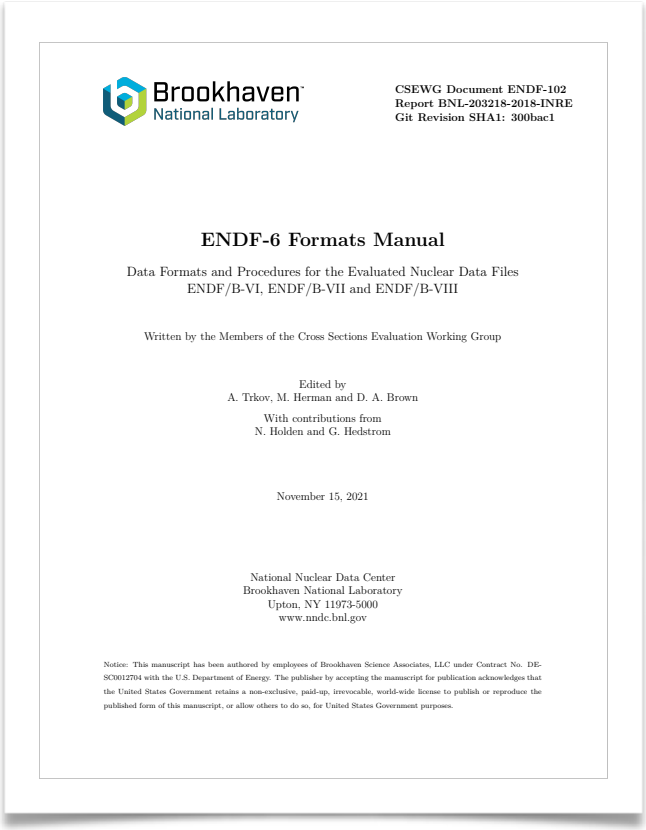
- New CSEWG Chair & ENDF Library Manager

"Big paper" to be published in NDS



Brookhaven National Laboratory

ENDF Formats



Brookhaven National Laboratory

CSEWG Document ENDF-102
Report BNL-203218-2018-INRE
Git Revision SHA1: 300bac1

ENDF-6 Formats Manual

Data Formats and Procedures for the Evaluated Nuclear Data Files
ENDF/B-VI, ENDF/B-VII and ENDF/B-VIII

Written by the Members of the Cross Sections Evaluation Working Group

Edited by
A. Trkov, M. Herman and D. A. Brown

With contributions from
N. Holden and G. Hedstrom

November 15, 2021

National Nuclear Data Center
Brookhaven National Laboratory
Upton, NY 11973-5000
www.nndc.bnl.gov

Notice: This manuscript has been authored by employees of Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the U.S. Department of Energy. The publisher by accepting the manuscript for publication acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this manuscript, or allow others to do so, for United States Government purposes.

ENDF Releases

Volume 148, February 2018 ISSN 0090-3752

ELSEVIER

Nuclear Data Sheets

A Journal Devoted to Compilations and Evaluations of Experimental and Theoretical Results in Nuclear Physics

E. A. McCutchan, Editor
National Nuclear Data Center, Brookhaven National Laboratory, Upton, NY 11973-5000, USA
www.nndc.bnl.gov

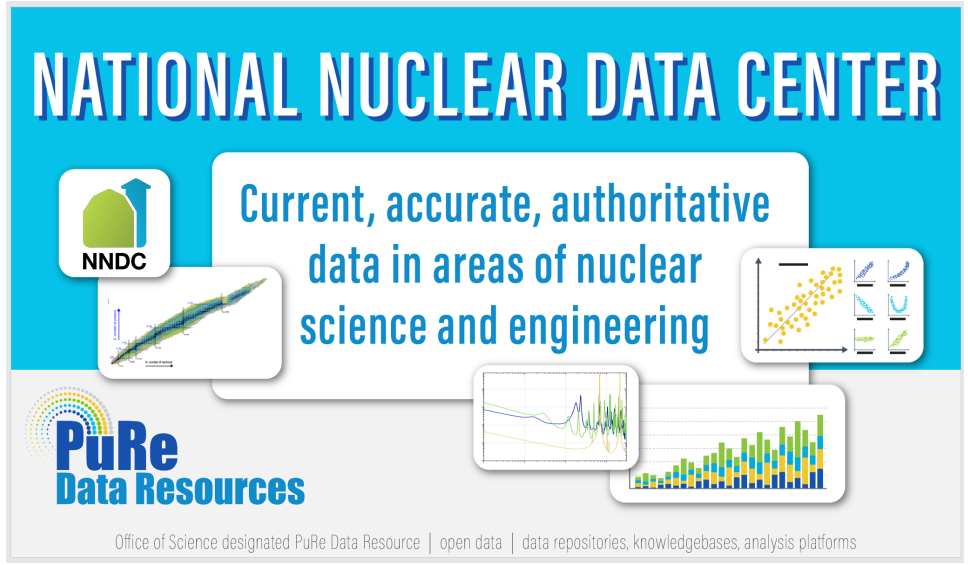
Special Issue on Nuclear Reaction Data

Special Issue Editor: Pavel Obložinský
Special Issue Assistant Editor: Boris Pritychenko

Contents

Contents continued on the back cover page

ENDF Files



Where to get the files

- In development files available at git.nndc.bnl.gov, contact G. Nobre (gnobre@bnl.gov) for access; note access is limited due to cost so please provide a justification

- All ENDF releases except ENDF/B-I available at www.nndc.bnl.gov, but locations may change…
  - We are assigning DOI's to libraries and generating proper landing pages
  - About ENDF/B-I, it is lost. If you have seen a copy, please email me

PuRe implementation status

Robust cloud backup since Sep. 2021

- One of a kind at BNL
- Backs up 15 TB of data from on-premise, mission-critical servers to AWS GovCloud
- Continuous replication
- During a disaster:
  1. Server backup restored from AWS GovCloud to create production-ready instance.
  2. Accessible within hours.
- Annual cost: $12k - $15k

Merging NNDC library with OSTI & BNL libraries

- C. Dunn cataloging & digitizing NNDC library
- OSTI gets digital copies, BNL gets paper

Our first DOI landing page – for the full ENSDF library!
ENSDF has a newly minted DOI, NSR & XUNDL are next!

PuRe Data Resources

https://www.osti.gov/dataexplorer/search/product-type:Dataset/doi:10.18139/nndc.ensdf/1845010

Final comments

- CSEWG is “here to help”
- Welcomes collaboration in and out of US (but inside is easier)
- Data is (when complete) OPEN
- Long tradition of quality/continuous improvement
- Conservative, driven by experiment when possible
- Golden Rule (whoever has the gold makes the rules)